GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF RESEARCH ADMINISTRATION

RESEARCH PROJECT INITIATION

Date: 1 May 1972

Project Title: Equipment Grant for Purchase of a Mass Spectrometer

Project No: G-33-646

Principal Investigator: Dr. W. M. Spicer

Sponsor: National Science Foundation

Agreement Period: From 1 April 1972 Until 30 September 1973

Type Agreement: Grant No. GP-32793

Amount:
$38,000 NSF Funds (G-33-646
37,135 GIT Contribution (G-33-336)
$75,135 Total cost of Mass Spectrometer

Reports Required:
Final Report

Sponsor Contact Person (s): Administrative

Mr. W. W Bolton, Jr.
Grants Officer
National Science Foundation
Washington, D. C. 20550

Assigned to: ~~School of Chemistry~~

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Patent Coordinator	Other_____

RA-3 (6-71)

GEORGIA INSTITUTE OF TECHNOLOGY

OFFICE OF RESEARCH ADMINISTRATION

RESEARCH PROJECT TERMINATION

Date: October 18, 1973

Project Title: "Purchase of a Mass Spectrometer"

Project No: G-33-646

Principal Investigator: Dr. W. M. Spicer

Sponsor: National Science Foundation

Effective Termination Date: 9/30/73

Clearance of Accounting Charges: all charges are clear

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Other _____

RA-4 (5/70)

G-33-646

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

CHEMISTRY

October 31, 1973

National Science Foundation
Washington, D. C. 20550

Attention: Dr. Richard S. Nicholson
Program Director for Chemical Instrumentation
Chemistry Section

Subject: Interim Research Instrument Report

Gentlemen:

The Chemistry Department at the Georgia Institute of Technology has prepared an interim report of the research investigations accomplished and those in progress which have been aided by the mass spectrometer purchased in part with funds from the National Science Foundation. A Hitchi RMU-7L Spectrometer was purchased with funds from the Chemical Instrumentation Grant GP-32793 of April 1972 and this instrumental facility has been operational since the summer of 1972 when a research technician, Mr. Larry Abbey, was added to our staff in order to operate and maintain the instrument. The Hitachi Mass Spectrometer has been an invaluable asset to our Department and greatly added to our scientific and educational productivity. The attached document outlines various research projects that have used this instrument and summarizes the results giving: published papers; manuscripts submitted; thesis completed; research programs in progress at the Post-Doctoral, Ph.D. and M.S. level; and undergraduate senior problems that have been completed.

Sincerely yours,

J. A. Bertrand, Director

JAB:lm

RESEARCH PROJECTS IN CHEMISTRY AT THE GEORGIA INSTITUTE OF TECHNOLOGY THAT HAVE BEEN AIDED BY THE NATIONAL SCIENCE FOUNDATION MASS SPECTROMETER CHEMICAL INSTRUMENTATION GRANT OF APRIL 1972

INTERIM REPORT

I PUBLISHED PAPERS

Published papers of research investigations at Georgia Tech that have been aided by the mass spectrometer purchased with funds from the National Science Foundation.

1. House, H. O., Auerbach, R. A., Gall, M., and Peet, N. P., "The Chemistry of Carbanions. XXII. C-Versus O-Acylation of Metal Enolates," J. Org. Chem.,38, 514 (1973).

2. House, H. O., Melillo, D. G., and Sauter, F. J., "Perhydroindan Derivatives. XV. The Synthesis of a Tetracyclic Percursor to Epiallogibberic Acid." J. Org. Chem., 38, 741 (1973).

3. House, H. O., and Umen, M. J., "The Chemistry of Carbanions. XXIV. Comparison of Stereochemistry in Alkylation and the Michael Reaction," J. Org. Chem.,38, 1000 (1973).

4. House, H. O., Koepsell, D., and Jaeger, W., "Derivatives of 1,8-Diphenylanthracene," J. Org. Chem.,38 1167 (1973).

5. House, H. O., and Melillo, D. G., "Perhydroindan Derivatives. XVI. The Synthesis of Racemic Epiallogibberic Acid," J. Org. Chem.,38, 1398 (1973).

6. House, H. O., Crumrine, D. S., Teranishi, A. Y., and Olmstead, H. D., "Chemistry of Carbanions. XXIII. Use of Metal Complexes to Control the Aldol Condensation," J. Amer. Chem. Soc.,95, 3310 (1973).

7. Caine, D., and Ingwalson, Paul F., "The Influence of Substituents on the Photochemical Behavior of Cross-Conjugated Cyclohexadienones. A Facile Total Synthesis of (-)-Cyclocolorenone," J. Org. Chem., 37, 3751 (1972).

8. Caine, D., Brake, P. F. DeBardelen, J. F., Jr., and Dawson, J. B., "The Influence of Electron-Withdrawing Substituents on the Photochemical Behavior of Bicyclic 6/6-Fused Cross-Conjugated Cyclohexadienones," J. Org. Chem., 38, 967 (1973).

9. Caine, D., Gupton, J. T., Ko Ming and Powers, W. J. "Photochemical Rearrangements of 6/5-Fused-Cross-Conjugated Cyclohexadienones in Proctic Solvents," J. Chem. Soc., Chem. Comm., 469 (1973).

10. Huffman, J. W., and Zalkow, L. H., "The Structure of Paradisiol and its Identity to Intermedeol. Terpenes XXXI," Tetrahedron Letters, 751 (1973).

11. Zalkow, L. H., Keinan, E., Steindel, S., Kalyanaraman, A. R., and Bertrand, J. A., "On the Absolute Configuration of Toxol at C-3. Vicinal H-H Coupling Constants in 2-Alkyl-3-hydroxydihydrobenzofurans," Tetrahedron Letters,2873 (1972).

PAPERS (cont.)

12. Zalkow, L. H., and Hill, R. H., "The Synthesis and Decomposition of a Norbornylendo Δ^2 -1, 2, 3 - Triazoline. Bridged Rind Compounds XIX," Tetrahedron Letters, 2819 (1972).

13. Zalkow, L. H. and Stiendel, S., "The Synthesis of 5β, 7β(H), 10α-Eudesm-4(14)en-1-one: Comments on the Structure of Canarone", Tetrahedron Letters, 3337 (1973).

14. Powers, J. C., and Tuhy, P. M., "Active-Site Specific Inhibitors of Elastase," J. Amer. Chem. Soc., 94, 6544 (1972).

15. Kurachi, K., Powers, J. C., and Wilcox, P. E., "The Kinetics of the Reaction of Chymotrypsin A_α with Peptide Chloromethyl Ketones in Relation to its Subiste Specificity," Biochem., 12, 771 (1973).

16. Powers, J. C., Baker, B. L., Brown, J., and Chelm, B. K., "Inhibition of Chymotrypsin A_α with N-Acyl and N-Peptidyl-2-Phenylethylamines. Subsite Binding Free Energies," J. Amer. Chem. Soc.,March 1974.

17. Powers, J. C. and Tuhy, P. M., "Active-Site Specific Inhibitors of Elastase," Biochemistry. November 1973.

18. Liotta, C. L., Fisher, W. F., Fisher, W. F., Greene, G. H., and Joyner, B. L., "Mechanism of Transmission of Nonconjugative Substituent Effects IV. Analysis of the Dissociation Constants of 6-Substituted Spiro [3.3] heptane-2-carboxylic Acids," J. Amer. Chem. Soc., 94, 4891 (1972).

19. Liotta, C. L., and Abidaud, A., "Direct Observation of the Reversible Formation of Anionic Sigma Complexes Related to Transition State Analogs for Adenosine Deaminase," J. Amer. Chem. Soc.,94, 7927 (1972).

20. Liotta, C. L., Fisher, W. F., Slighton, E. L., Harris, C. L., "σ-Inductive Model vs. Field Model Observation of a Reversed Attenuation Effect," J. Amer. Chem. Soc., 94, 2129 (1972).

21. Liotta, C. L., Perdue, E. M., Hopkins, H. P., "Thermodynamics of Acid-Base Equilibria III. Ionization of Substituted Anilinium Ions", J. Amer. Chem. Soc.,95, 2439 (1973).

II MANUSCRIPTS SUBMITTED

Submitted manuscripts of research investigations at Georgia Tech that have been aided by the mass spectrometer purchased with funds from the National Science Foundation.

1. House, H. O., and Umen, M. J., "The Chemistry of Carbanions XXV. The Reaction of Various Organocopper Reagents with α, β-Unsaturated Carbonyl Compounds," accepted for publication in J. Org. Chem.

2. House, H. O., and Kinloch, E. F., "Reactions Involving Electron Transfer IV. Reduction of Enones with Chromium (II) Compounds," submitted to J. Org. Chem.

3. House, H. O., and Kinlock, E. F., "Reactions Involving Electron Transfer. V. Reduction of Nonconjugated Acetylenes," submitted to J. Org. Chem.

4. Powers, J. C., Lively, M. O., Tippett, J. T. "Inhibition of Subtilisin BPN' with Peptide Chloromethyl Ketones" submitted to Biochemistry.

5. Liotta, C. L., and Cook, F. L., "Concerning the Decarboxylations of Geminal Diesters, β-Keto Esters and α-Cyano Esters Effected by Sodium Chloride in Wet Dimethyl Sulfoxide", submitted to Tetrahedron Letters.

6. Spaulding, L. D., Eller, P. G. , Bertrand, J. A., and Felton, R. H., "The Crystal and Molecular Structure of the Radical, Perchloratotetraphenylporphinatozinc (II)," submitted to J. of Amer. Chem. Soc.

7. Guzinski, J. A. and Felton, R. H., "Meso-tetraphenylmethoxyisoporphyrin Iron (III) Chloride", submitted to Chem. Comm.

III THESIS COMPLETED

Thesis completed at Georgia Tech that have been aided by the mass spectrometer purchased with funds from the National Science Foundation

PH. D. CATEGORY

Name	Title of Thesis	Thesis Advisor
F. T. Helm	"Structural Chemical Studies of Some Shiff Base Complexes of the First Row Transition Metal Elements"	Dr. J. A. Bertrand
T. Longfield	"Reaction of Cs with Aromatic Hydrocarbons	Dr. E. Grovenstein
J. Rhee	"1,4 Migration of the p-Biphenylyl Group in the Reactions of 4-Chloro-1-p-Biphenylyl-p, 1-Diphenylbutane with Alkali Metals"	Dr. E. Grovenstein
D. Melillo	"The Total Synthese of Racimic Epilallogibberic Acid"	Dr. H. O. House
M. J. Umen	"Stereo Chemistry of Enolate Anion Alkylation; Reactions of Enones with Cuprate Reagents"	Dr. H. O. House
E. F. Kinlock	"Reactions Involving Electron Transfer"	Dr. H. O. House
R. H. Hill, Jr.	"The Chemistry of Endo Triazolines"	
S. J. Steindel	"Studies in the Structure and Synthesis of some Natural Products"	Dr. L. Zalkow
Ko Ming	"Substituent Effect on Photochemical Rearrangements of Cross-Conjugated Cyclohexadrenones Related to Indanone"	Dr. D. Caine
P. F. Ingwalson	"Part I. Total Synthesis of (-)-Cyclocolorenone Part II. Total Synthesis of (±)-α-Vetispirene"	Dr. D. Caine

THESIS COMPLETED PH. D. CATEGORY (cont.)

Name	Title of Thesis	Thesis Advisor
A. Abidaud	"Aromatic Nucleophiler Substitution in Non-Polar, Aprotic Solvents"	Dr. C. L. Liotta
J. J. Walker	"Synthesis of Barbituric Acid Derivatives"	Dr. J. A. Stanfield

M. S. CATEGORY

T. C. Hightower	"A Study of Transition Metal Cubane-Type Complexes: Metal Ions in Mixed Oxidation States"	Dr. J. A. Bertrand
W. F. Pennington	"Synthesis and Stereo-chemistry of Metal-Ammonia Cleavage of a Conjugated Cyclopropyl Ketone"	Dr. D. S. Caine
J. T. Tippett	"The Kinetics of the Reac-tion of Subtilisn BPN' with Chloromethyl Ketones in Relation to its Subsite Specificity"	Dr. J. C. Powers

IV RESEARCH IN PROGRESS

Research in progress at Georgia Tech that is making use of the mass spectrometer purchased with funds from the National Science Foundation

POST-DOCTORAL INVESTIGATIONS

Name	Title of Research	Thesis Advisor
Dr. G. Eller	"Polynuclear Complexes of Transition Metals"	Dr. J. A. Bertrand
Dr. R. E. Williamson	"Rearrangements of Organoalkali Compounds"	Dr. E. Grovenstein,Jr.
Dr. W. P. Liang	"Anion Radical Cyclizations"	Dr. H. House
Dr. A. Fried	" Heterocyclic Chemistry"	Dr. Burgess
Dr. A. Abidaud	"Solute-Solvent Interaction"	Dr. Liotta

PH. D. THESIS

W. F. Willard	"Stereospecific Alkylation"	Dr. Ashby
D. E. Guest	"Reactions of Cesium and Cesium Alloys with Aromatic Hydrocarbons"	Dr. Grovenstein
A. B. Cottingham	"Rearrangements of 2,2-Diphenyl-4-pentenyl Anion"	Dr. Grovenstein
E. Zaiko	"Synthesis of Gibbirellins"	Dr. House
T. Maurer	"Synthesis of Nitroso-Ylids	Dr. Burgess
R. Nagy	"Thio-nitroso Compounds"	Dr. Burgess
C. Y. Chu	"Photochemical Interconvensins of Sesquiterpenes"	Dr. Caine
G. Hasenhuettl	"Total Synthesis of Euparotin"	Dr. Caine
J. T. Gupton III	"Total Synthesis of Aromadendrene"	Dr. Caine

RESEARCH IN PROGRESS PH. D. THESIS (cont.)

Name	Title of Thesis	Thesis Advisor
A. A. Boucuganni	"Reduction Cleavage of Cyclopropyl Ketones"	Dr. Caine
S. Forbeze	"Synthetic Approaches to Cadinane Sesquiterpenes"	Dr. Caine
M. Smith	"The Synthesis of Sesquiterpenoids"	Dr. Zalkow
C. Clower	"The Chemistry of Bicyclic Triazolines"	Dr. Zalkow
R. Calhoun	"The Chemistry of Bicyclic Triazolenes and Azindines"	Dr. Zalkow
J. Novak	"The Synthesis of Diterpenoids"	Dr. Zalkow
Ron Whitley	"Protease Studies"	Dr. Powers
Peter Tuhy	"Enzyme Engineering"	Dr. Powers
Dave Carroll	"Protein Crystallographic Studies"	Dr. Powers
Henry Harris	"Chemistry of 'Naked' Anions"	Dr. Liotta
Fred Cooke	"Polyacrylonitrile Models"	Dr. Liotta
Thomas Henson	"Transmission of Electrostatic Effects"	Dr. Liotta

M. S. THESIS

D. Liles	"Photochemistry of Methoxy Substituted Cyclohexadienones"	Dr. Caine

V UNDERGRADUATE (SENIOR) RESEARCH

Undergraduate senior research problems at Georgia Tech that have been aided by the mass spectrometer purchased with funds from the National Science Foundation.

Name	Title of Work	Advisor
A. Arduengo	"Thiocarbonyl Ylids"	Dr. Burgess
C. K. VanCantfort	"Endo Triazolines"	Dr. Zalkow
M. Lively	"Inhibition of Subtilisin"	Dr. Powers
K. Hohenstein	"Enzyme Engineering"	Dr. Powers
B. Chelm	"Enzyme-Substrate Binding Free Energies"	Dr. Powers
M. MacDermott	"Chemistry of 'Naked' Anions"	Dr. Liotta

[Reprinted from the Journal of Organic Chemistry, 38, 1398 (1973).]

Perhydroindan Derivatives. XVI. The Synthesis of Racemic Epiallogibberic Acid

Herbert O. House and David G. Melillo

[Reprinted from the Journal of Organic Chemistry, 38, 967 (1973).]

The Influence of Electron-Withdrawing Substituents on the Photochemical Behavior of Bicyclic 6/6-Fused Cross-Conjugated Cyclohexadienones[1]

DRURY CAINE,* PERRY F. BRAKE, JOHN F. DEBARDELEN, JR., AND J. BYRON DAWSON

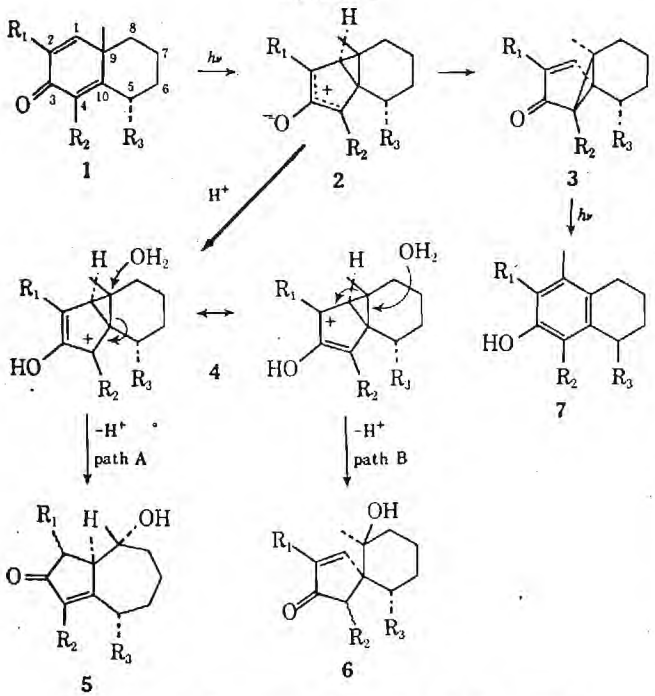
School of Chemistry, Georgia Institute of Technology, Atlanta, Georgia 30332

Received September 25, 1972

Derivatives of the bicyclic 6/6-fused cross-conjugated cyclohexadienone, 3-keto-9-methyl-$\Delta^{1,4}$-hexahydronaphthalene (**1j**), with electron-withdrawing formyl, carbonyl, and carbomethoxyl groups at positions 2 and 4 were synthesized and irradiated in aqueous acetic acid and in some cases other solvents. Each of the 2-substituted dienones was converted photochemically into a hydroazulene derivative in good yield. The 2-carboxy dienone **1e** proved to be an exceedingly useful compound for the synthesis of ring A unsubstituted hydroazulenes, as decarboxylation of the initial rearrangement products occurred spontaneously. The 4-formyl and 4-carbomethoxy dienones **1i** and **1g** failed to yield identifiable products having a rearranged carbon skeleton. In these cases it is possible that photochemical deconjugation to an enol of a β-dicarboxyl compound took place in preference to the normal cyclohexadienone rearrangement. However, the 4-carboxy dienone **1h** yielded spiro[4.5]decane derivatives on irradiation in aqueous acetic acid and in dioxane. In general, the mode of rearrangement of the substituted dienones can be intrepreted in terms of pathways generally accepted to be involved in cross-conjugated dienone rearrangements provided that the electron-withdrawing influence of the substituent and the ability of carboxyl substituents to act as internal proton donors to carbonyl groups are recognized.

The photochemical behavior of ring A unsubstituted and 2- and 4-methyl substituted cross-conjugated cyclohexadienones such as **1** (Scheme I) has been widely

SCHEME I



a, $R_1 = R_2 = H$; $R_3 = CH_3$ **d**, $R_2 = R_3 = H$; $R_1 = CHO$
b, $R_1 = R_3 = H$; $R_2 = CH_3$ **e**, $R_2 = R_3 = H$; $R_1 = CO_2H$
c, $R_2 = R_3 = H$; $R_1 = CH_3$ **f**, $R_2 = R_3 = H$; $R_1 = CO_2CH_3$
g, $R_1 = R_3 = H$; $R_2 = CO_2CH_3$
h, $R_1 = R_3 = H$; $R_2 = CO_2H$
i, $R_1 = R_3 = H$; $R_2 = CHO$
j; $R_1 = R_2 = R_3 = H$

studied.[2] The products of irradiation of dienones of this type are generally considered to arise *via* dipolar cyclopropyl intermediates such **2**, first proposed by Zimmerman and Schuster.[3a,4,5] Bicyclo[3.1.0]hex-2-en-3-one derivatives (lumiproducts) **3a–c**, which are obtained in good yield on irradiation of the corresponding dienones in neutral solvents such as dioxane,[6a–c] may be considered to arise *via* a symmetry-allowed 1,4-sigmatropic rearrangement of **2**.[7–9] However, when protic solvents such as aqueous acetic acid are employed, **2** too may be protonated to give the mesoionic species **4** which may undergo solvolytic cleavage to produce 5/7-fused or spiro hydroxy ketones. The mode of cleavage of **4** is apparently controlled by the electronic effect of methyl substituents. For example, on irradiation in aqueous acetic acid the 4-methyl dienone **1b** yielded exclusively the 5/7-fused hydroxy ketone **5b**,[10] while the 2-methyl compound **1c** yielded exclusively the spiro hydroxy ketone **6c**.[6c] Under similar conditions the unsubstituted dienone **1a** yielded an approximately 1:1 mixture of **5a** and **6a**.[6a] [In each case the hydroxy ketone products were accompanied by varying amounts of phenols (**7**), considered to arise as secondary photoproducts from the related lumiproducts.][2] Thus the location of an electron-releasing methyl group at C-4 or C-2 appears to increase the stability of the resonance form of **4** having a positive charge at that position and cleavage *via* path A or B takes place; and, when ring A of the dienone is unsubstituted, both resonance forms of **4** are approximately equal in energy so that products derived from both possible cleavage pathways are isolated.

(1) This investigation was supported by Public Health Service Research Grants No. GM 15044 from the National Institute of General Medicine and No. Ca 12193 from the National Cancer Institute, by a Frederick Gardner Cottrel grant-in-aid from the Research Corporation, and by a NASA Institutional Grant (NsG-657).

(2) For recent reviews see (a) P. J. Kropp, *Org. Photochem.*, **1**, 1 (1967); (b) K. Schaffner, *Advan. Photochem.*, **4**, 81 (1966).

(3) (a) H. E. Zimmerman[3b] and D. I. Schuster, *J. Amer. Chem. Soc.*, **84**, 4527 (1962); (b) H. E. Zimmerman and J. S. Swenton, *ibid.*, **86**, 947 (1964); (c) H. E. Zimmerman and J. S. Swenton, *ibid.*, **89**, 906 (1967).

(4) Zimmerman and coworkers[3a–c] have presented a detailed treatment of the mechanistic pathways by which species analogous to **2** may be formed photochemically from the parent dienone.

(5) For recent evidence for the intervention of dipolar intermediates in dienone photolysis see (a) M. H. Fisch, *Chem. Commun.*, 1472 (1969); (b) D. I. Schuster and V. Y. Abraitys, *ibid.*, 419 (1969); (c) D. I. Schuster and K. Liu, *J. Amer. Chem. Soc.*, **93**, 6711 (1971).

(6) (a) P. J. Kropp and W. F. Erman, *ibid.*, **85**, 2456 (1963); (b) P. J. Kropp, *ibid.*, **87**, 3914 (1965); (c) P. J. Kropp, *ibid.*, **86**, 4053 (1964).

(7) (a) H. E. Zimmerman and D. S. Crumrine, *ibid.*, **90**, 5612 (1968); (b) H. E. Zimmerman, D. S. Crumrine, D. Dopp, and P. S. Huyffer, *ibid.*, **91**, 434 (1969).

(8) T. M. Brennam and R. K. Hill, *ibid.*, **90**, 5614 (1968).

(9) R. B. Woodward and R. Hoffman, *Angew. Chem., Int. Ed. Engl.*, **8**, 781 (1969).

(10) (a) P. J. Kropp, *J. Org. Chem.*, **29**, 3110 (1964); (b) D. Caine and J. B. Dawson, *ibid.*, **29**, 3108 (1964).

[Reprinted from the Journal of Organic Chemistry, 38, 741 (1973).]

Perhydroindan Derivatives. XV. The Synthesis of a Tetracyclic Precursor to Epiallogibberic Acid

Herbert O. House, David G. Melillo, and Frederick J. Sauter

[Reprinted from the Journal of Organic Chemistry, 38, 1000 (1973).]

The Chemistry of Carbanions. XXIV. Comparison of Stereochemistry in Alkylation and the Michael Reaction

Herbert O. House and Michael J. Umen

[Reprinted from the Journal of the American Chemical Society, 95, 3310 (1973).]

Chemistry of Carbanions. XXIII. Use of Metal Complexes to Control the Aldol Condensation

Herbert O. House, David S. Crumrine, Allan Y. Teranishi, and Hugh D. Olmstead

Reprinted from

Tetrahedron Letters No. 10, pp 751 - 754, 1973. Pergamon Press. Printed in Great Britain.

THE STRUCTURE OF PARADISIOL AND ITS IDENTITY TO INTERMEDEOL

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(Received in USA 30 November 1972; received in UK for publication 25 January 1973)

The currently accepted biosynthetic paths leading to the vetivane and nootkatane groups

Photochemical Rearrangements of 6/5-Fused Cross-conjugated Cyclohexadienones in Protic Solvents

By Drury Caine,* John T. Gupton III, Ko Ming, and William J. Powers III
(*School of Chemistry, Georgia Institute of Technology, Atlanta, Georgia* 30332)

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Journal of The Chemical Society
Chemical Communications
1973

The Chemical Society, Burlington House, London W1V 0BN

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Thermodynamics of Acid–Base Equilibria. III. Ionization of Substituted Anilinium Ions

Charles L. Liotta,*[1a] Edward M. Perdue,[1a] and Harry P. Hopkins, Jr.[1b]

Contribution from the School of Chemistry, Georgia Institute of Technology, Atlanta, Georgia 30332, and the Department of Chemistry, Georgia State University, Atlanta, Georgia 30303. *Received June 16, 1972*

Abstract: The standard enthalpies of ionization of 21 meta- and para-substituted anilinium ions have been determined calorimetrically in aqueous solution at 25°. Standard entropies of ionization have been calculated from the experimental enthalpies of ionization and the literature Gibbs free energies of ionization. Both the enthalpies and entropies of ionization show a good linear correlation with the Gibbs free energy of ionization. The experimental results have been analyzed in terms of Hepler's theory of substituent effects and have been compared to the predictions of electrostatic theory.

Because of the theoretical and practical interest in the ionization of organic acids in aqueous solution, numerous determinations of the thermodynamic functions of ionization for these acids have appeared in the literature. A recent review article by Larson and Hepler has summarized the available data.[2]

Reliable Gibbs free energies of ionization or pK_a's have now been obtained in aqueous solution for a majority of the known organic acids. However, the enthalpies and entropies of ionization are needed if the details of the ionization process are to be fully understood. Hepler and coworkers[2] have shown that the variation in the pK_a's of substituted phenols is almost entirely due to changes in the entropy of ionization. An analysis of the enthalpies and entropies of ionization of a wide variety of structurally different mono- and dicarboxylic acids by Christensen, Izatt, and Hansen[3] has shown that the Gibbs free energies of ionization correlate extremely well with the entropies of ionization whereas neither the Gibbs free energies nor the entropies demonstrate a distinct correlation with the enthalpies of ionization. This lack of a good correlation between the enthalpies of ionization and the other thermodynamic functions is probably due to the inherent difficulty in making accurate determinations of the very small enthalpies of ionization of carboxylic acids.

Recently Bolton, Fleming, and Hall[4] have reported a spectrophotometric determination of the thermodynamic functions of ionization for a number of meta- and para-substituted benzoic acids. Excellent correlations were obtained not only between $\Delta G°$ and $\Delta S°$, but also between $\Delta G°$ and $\Delta H°$. If it is assumed that the experimental uncertainty is on the order of ± 50 cal/mol for $\Delta H°$, then correlation between $\Delta G°$ and $\Delta H°$ may be considered fortuitous at best.

In ionogenic processes such as the ionization of phenols and carboxylic acids, it has been established that entropy differences are mainly responsible for relative acidities of these acids. The study of a system involving organic cation acids would determine the relative

(1) (a) School of Chemistry, Georgia Institute of Technology; (b) Department of Chemistry, Georgia State University.

(2) J. W. Larson and L. G. Hepler, "Solute-Solvent Interactions," J. F. Coetzee and C. D. Ritchie, Ed., Marcel Dekker, New York, N. Y., 1969.

(3) J. J. Christensen, R. M. Izatt, and L. D. Hansen, *J. Amer. Chem. Soc.*, 89, 213 (1967).

(4) P. D. Bolton, K. A. Fleming, and F. M. Hall, *ibid.*, 94, 1033 (1972).

[Reprinted from the Journal of Organic Chemistry, 38, 514 (1973).]

The Chemistry of Carbanions. XXII. C- *vs.* O-Acylation of Metal Enolates

Herbert O. House, Robert A. Auerbach, Martin Gall, and Norton P. Peet